Control System Design

References

1. Feedback Control of Dynamic Systems (6th Ed)
   Franklin, Powell and Emami-Naeini, Addison Wesley, 2002.

2. Modern Control Systems (11th Ed)


History of Automatic Control

B.C.
- 300: water-level float regulator

A.D.
- 1770s (Feedback control)
- 1769 James Watt: steam engine (flyball governor)

James Watt (1736-1819)
History of Automatic Control

- 1877 E.J. Routh: stability of high order systems
- 1907 A.M. Lyapunov: stability of equation of motion (state space form Poincare’ 1892)
- 1913 H. Ford: automation
- 1927 H.W. Bode: feedback amplifier analysis (frequency domain approach)
- 1932 H. Nyquist: stability criterion for frequency domain approach
- 1936 Callender: PID controller
- 1948 W.R. Evans: the root locus approach

Edward John Routh (1831-1907)  James Clerk Maxwell (1831-1879)
Aleksandr Mikhailovich Lyapunov (1857-1918)

1950s (Optimal control)
- 1952 MIT: NC machine
- 1954 Robotic control
- 1956 Bellman: dynamic programming (USA)
- 1960 Kalman: MIMO problem controllability & observability
- 1961 Kalman & Bucy: Kalman-Bucy filter

- 1963 Pontryagin: maximum principle, time optimal controller and optimal controls for linear systems with a quadratic cost function
- 1964 Kalman: design procedure for linear optimal control problem with quadratic performance criterion
History of Automatic Control (Cont.)

- 1970s (Frequency domain design method for MIMO systems)
- 1969 Rosenbrock: inverse Nyquist array method
- 1970 MacFarlane, Postlethwaite, Edmunds and Kovaritakis: Characteristic locus method

http://en.wikipedia.org/wiki/Alistair_MacFarlane

Ian Postlethwaite

History of Automatic Control (Cont.)

- 1976 Youla: stable factorization technique
- 1983 Zames & Francis: H-infinity control theory
- 1984 Barmish: robust stability with structure physical parameter perturbations
- 1986 M. Athans: LQG/LTR design method

Control Systems

- General system
  A system is a collection of components which interact with each other and with the environment (by information or energy links) from which the system is separated by a notational boundary.
Structure of a Feedback Control System

**Process**: the device, plant, or system under control.

**Sensor**: a device to measure signal of interest

**Actuator**: a device to amplify the control signal and to drive the plant.

![Control System Diagram](image)

Problems Formulation

- **Control system**
  A control system is a system capable of monitoring and regulating the operation of a process or a plant. The study of control system is essentially a study of an important aspect of systems engineering and its applications.

- **Problem formulation**
  Determine a control law to stabilize the system and to achieve asymptotic reference tracking and disturbance rejection.

Open-loop control

An open-loop control is applied to achieve desired system response using a controller or an actuator without feedback.

Closed-loop/feedback control

A closed-loop control is used to achieve desired system response using a controller with the output measurement as a feedback signal. The use of feedback enables us to improve system performance at the cost of introducing the measurement noise and stability problem.

(a) The F-18 aircraft, one of the first production military fighters to use “fly-by-wire” technology, and

(b) the X-45 (UCAV) unmanned combat aerial vehicle. (Photographs courtesy of NASADryden Flight Research Center.)
Aircraft flight control system

Ship Autopilot Control System

Tracking Control System of a Missile

Examples of Control System
Control Engineering Practice

- Control engineering is concerned with the analysis and design of goal-oriented (task-oriented) systems. Control systems are used to achieve:
  - increased productivity and
  - improved performance.

- **Main tasks of control engineering**
  - Modelling, Analysis, Design and Development.

- **Automation**
  - The control of industrial process (manufacturing, production, etc.) by automatic rather than manual means is called automation.

- **Robust control**
  - The system can be controlled by the controller in a desired manner, in spite of the allowable disturbances and changes in the system parameters/uncertainties.

- **Intelligent control system**
  - The system has capabilities of planning, scheduling, adaptation, and learning.
Control System Design

Engineering design is the main task of the engineer.

Specifications
The closed-loop control system performance specifications include:

1) good regulation against disturbance,
2) desirable responses to commands,
3) realistic actuator signal,
4) low sensitivity, and
5) robustness

The design is to achieve appropriate design specifications and rests on four characteristics: complexity, tradeoffs, gaps and risk.

Journals

AIAA Journal of Guidance, Control, and Dynamics.
Automatica.
Control Engineering Practice.
IEEE Control Systems Magazine.
IEEE Transactions on Automatic Control.
IEEE Transactions on Control Systems Technology.
International Journal of Control.
International Journal of Robust and Nonlinear Control.
Mechatronics.
SIAM Journal on Control and Optimization.
Systems and Control Letters.
Transactions of the Institute of Measurement and Control.

You are ready to explore the world of control systems.